A PRELIMINARY ASSESSMENT OF CISTERN WATER QUALITY IN SELECTED HOTELS AND GUEST HOUSES IN THE U.S. VIRGIN ISLANDS

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 The authors of this report wish to emphasize that the results of the study are only preliminary, and no generalized inferences should be drawn based upon this report.

ABSTRACT

Tourism is the most important industry in the Virgin Islands, which brings in millions of dollars of revenue to the local government. Since maintaining good water quality is important for tourism, an attempt was made in this preliminary study to assess the bacteriological quality of cistern water in selected hotels, resorts, and guest houses on St. Thomas, U.S. Virgin Islands.

Our results indicate considerable variability in cistern water quality between different hotels and guest houses. Those establishments that maintained close supervision with regard to disinfection procedures maintained water quality that was acceptable under the Safe Drinking Water Standards. There were, however, other establishments which were unable to provide water of acceptable quality for drinking purposes.

While total coliform count and turbidity are the established indicators of cistern water quality at the present time, testing for fecal coliforms and Pseudomonas aeruginosa may be more appropriate to ensure the safety of cistern water in the Virgin Islands.

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INTRODUCTION

The number one industry in the Virgin Islands is tourism, which brings in millions of dollars of revenue to the local government. On St. Thomas there are six hotels with more than 100 rooms; however, an estimated 75 percent of all lodging places have 50 or fewer rooms. The mountainous terrain makes water distribution a problem. The solution has been the development of cistern water systems.

Under the Virgin Islands Code, every building (except for federal buildings which are exempt from the local code) must have its own cistern. This includes all hotels and guest houses. These cisterns range from small 1,500 gallon cisterns for small residential cottages, to a large 700,000 gallon system which supplies all the water needs of a hotel complex in St. Thomas.

As part of an ongoing investigation into cistern water quality in the territory, we focused on cistern water quality of a few randomly selected hotels and guest houses on St. Thomas for purposes of comparing the results to the Safe Drinking Water Standards (SDWS). The results are to be used to assess if those standards are the best ones to use for cistern water systems, or whether standards specific for such systems should be established.

While cisterns may vary in size and construction, as well as the type of water they may hold (rain, trucked in, potable, well water, and RO/distilled water), all cisterns share some common features which set them apart from a potable water supply. These include being exposed to the environment, thus subjected to external contamination; and being built in conjunction with a roof-top collection system for the harvesting of rainfall.

Hotels and guest houses (Inns) in the Virgin Islands are mandated under the Safe Drinking Water Act of 1974 and as amended in 1986 to have their water tested on a quarterly basis. Currently, only the total coliform count and turbidity of the sample are required under the Safe Drinking Water Act (SDWA) of 1974 and as amended in 1986. If the sample contains more than 1 total coliform per 100 mL, and/or has a turbidity greater than 1.0 NTU, the sample is in violation of the mandates of the Safe Drinking Water Standards (SDWS). Next year additional tests will be required. In the event a sample tests positive for total coliforms, repeat samples must be collected within 24 hours of notification, in addition the total coliform positive sample must be analyzed for fecal coliforms or E. coli. Finally the hotel must maintain a disinfectant residual at all times of no less than 0.2 mg/L; in lieu of this the hotel may substitute heterotrophic plate counts (Standard Plate Count). If the count does not exceed 500 total organisms per mL, the system is considered to have a "detectable" residual for compliance purposes. Systems in violation of this requirement must install filtration unless the State determines that the violation was not caused by a deficiency of treatment of the source water (34). The standards for pH and conductivity are more aesthetic than practical and are rarely enforced. The pH should be as close to neutral as possible between 6.5 - 8.5. Total dissolved solids (TDS) which cause conductivity, should be less than 500 mg/L.

The total coliform bacteria has been the indicator of choice in determining potable water quality since 1914 (4). Since coliforms are frequently associated with fecal contamination, the presence of coliforms in a potable water supply indicates that the supply has been contaminated. As the number of coliforms increase, so does the probability of encountering enteric pathogens since there is a high degree of correlation between coliforms and enteric pathogens (4,5,24).

In two previous cistern studies we found that 74 percent of the samples from privately owned cisterns, and 49 percent of the samples from public housing cisterns were not in compliance with the Safe Drinking Water Standards. The environment in which the cisterns are in close contact with has an abundance of coliform bacteria (11,14,19,28,29) which are not necessarily of human origin. They are frequently present in the leaf debris, dust, soil deposits, and animal droppings which may have accumulated on the roof and in the gutters (11,28,29). Also, the total coliform standard does not adequately predict the occurrence of Pseudomonas aeruginosa, a naturally occurring opportunistic pathogen found in soil and water (13,25); our studies show that there is no correlation between it and the total coliform (16,29). Indeed in both of the studies mentioned before, Ps. aeruginosa was found in 69 percent and 49 percent of the private residential and public housing cisterns respectively, with it being present in the absence of total coliform almost 16 percent of the time on average.

While most Virgin Islanders drink their own cistern water, with many claiming to suffer no ill effects, visitors may not be immune since most of them come from large cities where drinking water is usually treated and protected from external contamination.

In this study, we attempted to make a preliminary assessment of cistern water quality in selected hotels and guest houses on St. Thomas in relation to the Safe Drinking Water Standards as set by the U.S. Environmental Protection Agency. In addition we determined the relative occurrence of the opportunistic pathogen Pseudomonas aeruginosa occurring in hotel and guest house cisterns and compared it to free chlorine residual. This study was also used to gather data upon which to base recommendations for alternate regulations for cistern stored water.

MATERIALS AND METHODS

Site selection. Initially 23 hotels and guest houses (Inns) were chosen for screening in the pilot phase of the study. During this phase hotels were screened based upon answers given in response to a questionnaire, and the results obtained from an initial total coliform test. The criteria used to select the hotels which were to take part in this study included the number of rooms available, allowing for grouping into large, moderate, and small categories; the total number of cisterns in the hotel, since one of the objectives was to study the total water quality of a selected hotel or guest house, (hotels or guest houses which had more than three cisterns were excluded); source/s of water in the cistern, as we wanted a representative sample of the most common water sources; disinfection practice and frequency; compliance or non-compliance with the testing regulation; and finally the results of the initial total coliform screen to see if any problem was existent. Based upon the results of this information, eleven hotels and guest houses were selected. Four were large hotels having more than 100 rooms, with a total of 6 cisterns; three were moderately sized hotels having between 30 and 99 rooms, with a total of 5 cisterns; and four were small guest houses having less than 30 rooms, with a total of 6 cisterns. The project thus consisted of a study of water samples from eleven hotels and guest houses containing a total of 17 cisterns over a 11 month period.

Within the selected study population 6 out of the 11 hotels studied (L 2 thru 4; M 3; and S 2,3) were tied directly into the potable water line which allows these owners/operators to simply open a valve to fill their cisterns as the water demand dictates. Five of the hotels (L 2; M 1,2; and S 3,4) relied upon trucked water to supply their needs. These hotels during the month of October and the first half of November, and then again from mid April to July -- months which correspond to the "off season" when there are fewer tourists -- did not tend to use as much water as during the "tourist season", mid November to mid April, when most of these hotels reported as constantly having to order water. Only hotel L 1 was totally self sufficient for their water needs relying upon Reverse Osmosis (R.O.) to provide their water needs. Hotel M 2 was in the process of installing an R.O. unit for their needs, but had to also rely from time to time on trucked water. Hotel S 1 did not initially use its cistern water, which is a mixture of well and rain water, for drinking purposes, choosing to rely on bottled water for those needs, but did use it for washing and bathing. Towards the end of the study they installed a small carbon-based and silver-impregnated filter system in an exploratory attempt to get away from the expense of bottled water. All hotels were equipped to gather rainwater.

Table 1 presents a summary of the results from the questionnaires from the 11 hotels.

Table 1: Cistern and water-related data in selected hotels/resorts/guest houses

Hotel ID	# Rms	# Cist.	Age of Cist. (yrs.)	Cistern Capacity (gal.)	Water Source/s	Water Treatment	How Often	Water Tested	How Often
L 1	300	3-into-1	New-23	376,000	Rain/R.O. Dist.	Y/Cl	Cont	Y	MO
L 2	170	3	30	Unavail.	Rain/Trucked Potable	Y/Cl	Passive Wk	Y	MO
L 3	150	2-into-1	9	56,000	Rain/Potable	Y/Cl	Passive Ea rain	Y	MO
L 4	239	2-into-1	2-30	134,000	Rain/Potable	Y/Cl	Bi/wk	Y	MO
M 1	49	3	20	Unavail.	Rain/Trucked	Y/Cl	Passive Mo	Y	MO
M 2	81	1	16	750,000	Rain/Trucked R.O.	Y/Cl	Cont	Y	MO
M 3	50	2-into-1	New-20	83,000	Rain/Potable	Y/Cl	Passive	Y	MO
S 1	13	1	36	60,000	Rain/Well	N	N.A.	Y	YR
S 2	15	2	37	20,000 Ea	Rain/Potable	N	Passive	N	N.A.
S 3	12	1	100	46,000	Rain/Potable Trucked	Y/Cl	Passsive Mo	Y	MO
S 4	15	2	1-30	68,000 Ea	Rain/Trucked	Y/U.V.	Always on Passive Cl	Y	QT

Passive chlorination = chlorine residual present in purchased water; not from owner involvement.
N.A. = Not Applicable
U.V. = Ultra Violet Light
Cl. = Chlorine
Cont. = Continuous

Sample collection procedures. Sample sites were divided by geographic location into three groups of five or six cisterns each. One group was sampled each week with the others being sampled in rotation. The average number of samples collected from the large, moderate and small size hotels were 6, 7 and 6 respectively. The dates on which samples were collected is shown in Appendix A.

Samples were collected in sterile 1 liter, clear borosilicate glass, wide mouth bottles with ground glass stoppers. Each bottle contained 0.8 mL of a 10% solution of the dechlorinating agent sodium thiosulfate (1,3)).

Samples were collected in accordance with Standard Methods for the Examination of Water and Wastewater (1). They were transported back to the laboratory in light protected containers. Samples were not chilled upon collection as analysis usually commenced within 2.5 hours of collection. All samples held over 6 hours were discarded to ensure the reliability of the data. While it has been noted that die off does occur even after only short intervals (21,22), the die off has been shown to be insignificant for the times involved (33).

Physical-chemical analyses. Measurements for free residual chlorine were performed on site by the DPD method (1) at the time of collection; measurements for pH, turbidity, conductivity were done upon arrival back at the laboratory, and in accordance with Standard Methods.

Microbiological analyses. Analyses for total coliform, fecal coliform, fecal streptococcus, Pseudomonas aeruginosa, and overall heterotrophic plate counts were performed on each sample. Total coliform, and fecal coliform analysis were performed in accordance with both Standard Methods (1), and Microbiological Methods for Monitoring the Environment: Water and Wastewater (3). All analyses with the exception of the heterotrophic plate count were done via the membrane filter (MF) technique. The heterotrophic plate count was done using the spread plate technique.

Total coliform, fecal coliform, and fecal streptococcus were isolated on m-Endo Agar (Difco Laboratories, Detroit, MI) (1,2,3), m-FC Agar (Difco) (1,2,3), and KF Streptococcus Agar (Difco) (1,2,3), respectively, The heterotrophic plate count (1) was performed using Standard Plate Count Agar (Difco). All media were prepared in accordance with the manufacturer's instructions. Analysis for Ps. aeruginosa were performed by non-standard methods as described below.

Sample volumes of 100, 50, 25, and 10 mL were filtered. Total coliform, fecal streptococcus (1,2,3), and Ps. aeruginosa (7,18) samples were filtered through 0.45 u filters (GN-6, 66068; Gelman Sciences Inc., Ann Arbor, MI.). Fecal coliform samples were filtered through 0.7 u filters

(Millipore Corporation, Bedford, Mass.) (1). 0.1 and 1 mL volumes of 3 dilutions ranging from 1 to 10^{-6} were run in duplicate for the heterotrophic plate counts.

Total coliforms, fecal streptococcus, and the heterotrophic plate counts were incubated at 35 $\pm$ 0.5^{o}C (1,3). Fecal coliform plates were incubated at 44.5 $\pm$ 0.2^{o}C (1,3). Total coliforms and fecal coliforms were incubated for 24 hours; fecal streptococcus, and heterotrophic plate counts were incubated for 48 hours (1,3).

Pseudomonas aeruginosa analysis. Ps. aeruginosa was isolated on a new medium, m-CX agar, developed in this laboratory (29), but is based on a modification of the highly successful formula of King et al (15). The Ps. aeruginosa plates were preincubated at 30 $\pm$ 0.5 ^{o}C for 3-4 hours and then incubated at 41.5 $\pm$ 0.5 ^{o}C (7,13,18,29) for the remaining 44 hours.

Verification of isolates. Up to five typical and, if present, five atypical colonies were picked from each medium for each sample, and subjected to verification (3). Colonies were counted with the aid of a variable magnification dissecting scope with a minimum magnification of 10x (Parco EMZ745 10L with annular fluorescent illumination; Parco Scientific Co., Bienna, OH) (1,3). The heterotrophic plate counts were counted with the aid of a Quebec Colony Counter (1,3).

Typical green sheen, and atypical red colonies were picked from the m-Endo Agar plates and verified in Lauryl Tryptose Broth (Difco) and Brilliant Green Bile 2% (Difco) (1,3).

Typical blue and atypical gray or blue-gray colonies from the m-FC Agar plates were verified in Lauryl Tryptose Broth and EC Medium (Difco) (1,2,3).

Typical red-pink to red colonies from the KF Streptococcus Agar plates were verified for growth in Brain Heart Infusion Broth (Difco) at 35 and 44.5 ± 0.2^{o} C; for growth in Brain Heart Infusion Broth with 40% Bile, and by the Catalase test (1,2,3).

Typical fluorescent yellow to yellow green or blue green, mucoid colonies and atypical small, clear, flat, non-mucoid colonies, were picked from the m-CX Agar plates (15,29) and verified on Skim Milk Agar (Brown and Foster) (1,7,18), Pseudomonas Isolation Agar (Difco)(6), and King's B medium (15) (same as Difco's Pseudomonas F Agar)(6).

RESULTS

To maintain anonymity, each cistern studied is identified only by number (e.g. L 1-3 for cistern 3 in large hotel 1). Table 2 presents the number of times each site was sampled as well as the average data over time for total coliform, fecal coliform, fecal streptococcus, Pseudomonas aeruginosa, and heterotrophic plate counts for each hotel cistern, broken down by class, as well as the average value for each parameter per class. The range of values for these parameters in each cistern are reported in Appendix B.

From Table 2 we find that of the 17 cisterns studied, 12 on average failed the SDWS of $\leq$ 1 total coliform per 100 mL; sixteen of the cisterns, however, met the standard at least once. Of the 12 cisterns which failed the total coliform standard on average, 8 had significant total coliform problems (an average total coliform count greater than 10), and of those eight, 6 showed significant fecal coliform problems as well. It should be noted however that ten of the 17 cisterns had fecal coliforms present and thus would have been in violation of an EPA limit of 0 per 100 mL had the proposed law been in effect. In addition 13 of the cisterns showed the presence of Ps. aeruginosa, of which 10 had levels which were $\geq$ 10.

Table 2: Average bacterial counts in cistern waters of large (L), moderate (M), and small (S) hotels.

Cistern No.	No. of Samples	Total Coliform[a]	Fecal Coliform[a]	Fecal Strep.[a]	Ps. aeruginosa[a]	Standard Plate Count[b]
L 1-1	8	3	0	8	88	12387
L 2-1	6	0	0	166	10	191
L 2-2	6	26	0	13	19	510
L 2-3	6	0	0	9	0	155
L 3-1	6	1	1	24	0	91
L 4-1	4	2	1	20	0	1451
	6	**5**	**0**	**40**	**20**	**2464**
M 1-1	7	6	2	4	2	2767
M 1-2	7	282	12	15	97	19113
M 1-3	7	106	16	61	135	34602
M 2-1	7	901	40	11	333	64284
M 3-1	6	18	38	104	1	614
	7	**263**	**22**	**39**	**114**	**24276**
S 1-1	7	102	7	69	23	2752
S 2-1	6	1	1	21	1	115739
S 2-2	6	4	0	42	61	3972
S 3-1	7	16	0	10	816	2010
S 4-1	6	115	6	11	598	21393
S 4-2	2	0	0	5	0	No Data
	6	**40**	**2**	**26**	**250**	**29173**

a = Counts per 100 mL.
b = Counts per mL.

Large hotels/resorts (L): > 100 rooms
Moderate size hotels (M): 30-99 rooms
Small hotels (S): < 30 rooms

Table 3 gives the average turbidity for each cistern in each class, the average pH, and conductivity. These data are included to show that the influence of these parameters in cistern water is minimal.

From Table 3 we find that 82% of all hotel and guest house cisterns in this study meet the turbidity standard of less than 1.0 NTU. The pH data show that in general, cistern water is only slightly alkaline (a pH of 7.00 is considered neutral). The very low conductivity data shows that there is very little salt or dissolved solids present in the water.

Table 4 presents a summary of the percentages of the samples which would meet the current SDWS of $\leq$ 1 total coliform per 100 mL, a suggested fecal coliform standard of $\leq$ 1 fecal coliform per 100 mL, a suggested heterotrophic plate count standard of $\leq$ 500 total organisms per mL, and the relative occurrence of Ps. aeruginosa in these samples as well as in the absence of the total coliform. Note that the large hotels defined as those with more than 100 rooms most frequently met the SDWS, meeting the standard 60% or more of the time, while the moderately sized hotels defined as those with 30 - 99 rooms were less consistent, meeting these standards between 43% and 60% of the time. The small hotels and guest houses were highly variable, ranging from 0 to 100% in meeting the standard. On average, they met the SDWS 59% of the time. The moderately sized hotels were consistent, meeting this standard 49% of the time, on average.

Table 3: Summary of pH, Conductivity, and Turbidity in Selected Hotel and Guest House Cisterns Average Values and (Ranges)

Cistern No.	pH	Turbidity (NTU)	Conductivity (uMHO)
L 1-1	6.79 (6.48 - 7.07)	0.37 (0.13 - 0.68)	341 (190 - 760)
L 2-1	8.86 (8.26 - 9.46)	0.52 (0.28 - 0.70)	209 (165 - 260)
L 2-2	8.64 (6.96 - 9.25)	0.72 (0.44 - 0.92)	222 (150 - 300)
L 2-3	8.88 (7.92 - 9.41)	0.62 (0.30 - 1.16)	212 (160 - 298)
L 3-1	7.62 (6.45 - 9.42)	1.28 (0.18 - 2.89)	215 (145 - 299)
L 4-1	6.99 (6.53 - 7.88)	0.82 (0.35 - 1.25)	198 (140 - 269)
	7.96 (7.10 - 8.75)	**0.72 (0.28 - 1.27)**	**233 (158 - 364)**
M 1-1	7.57 (6.75 - 9.15)	0.51 (0.25 - 0.98)	178 (125 - 240)
M 1-2	7.93 (7.01 - 9.20)	0.61 (0.40 - 0.73)	271 (190 - 630)
M 1-3	7.91 (7.10 - 8.72)	0.67 (0.25 - 1.58)	246 (180 - 500)
M 2-1	7.91 (7.00 - 9.03)	0.58 (0.18 - 0.89)	710 (100 - 1200)
M 3-1	7.91 (6.52 - 9.16)	1.08 (0.23 - 2.30)	212 (140 - 320)
	7.85 (6.88 - 9.05)	**0.69 (0.26 - 1.30)**	**323 (147 - 578)**
S 1-1	7.74 (7.61 - 7.85)	0.63 (0.27 - 1.34)	1424 (170 - 1900)
S 2-1	7.91 (6.83 - 9.06)	0.26 (0.11 - 0.38)	204 (160 - 240)
S 2-2	7.88 (6.89 - 8.61)	0.40 (0.16 - 0.81)	299 (200 - 520)
S 3-1	8.26 (7.00 - 9.10)	0.89 (0.47 - 2.65)	236 (180 - 339)
S 4-1	7.49 (6.94 - 8.42)	0.43 (0.32 - 0.65)	177 (125 - 249)
S 4-2	8.90 (8.90 - 8.90)	3.92 (1.28 - 6.55)	190 (180 - 200)
	8.03 (7.36 - 8.66)	**1.09 (0.44 - 2.06)**	**422 (169 - 575)**

Table 4: Summary of cistern water quality in selected large (L), moderate (M), and small (S) hotels

Cistern No.	% of samples meeting SDWS	% of samples meeting a FCS*	% of samples meeting a HPCS**	% of samples + for Ps. aeruginosa and (in the absence of Total Coliform)	% of samples with Free Cl
L 1-1	63	86	75	29 (0)	88
L 2-1	100	100	75	17 (17)	100
L 2-2	86	100	50	17 (17)	100
L 2-3	100	100	75	17 (17)	100
L 3-1	86	83	100	0 (0)	100
L 4-1	60	75	50	0 (0)	100
	83%	**91%**	**71%**	**13% (9%)**	**98%**
M 1-1	50	71	20	43 (14)	13
M 1-2	43	67	20	67 (17)	43
M 1-3	43	43	0	17 (17)	29
M 2-1	50	86	20	86 (43)	25
M 3-1	60	83	67	0 (0)	100
	49%	**70%**	**25%**	**43% (18%)**	**42%**
S 1-1	0	14	0	100 (0)	0
S 2-1	86	83	60	40 (33)	71
S 2-2	71	100	40	67 (50)	43
S 3-1	25	100	33	88 (14)	57
S 4-1	71	83	40	33 (0)	N.A.
S 4-2	100	100	No data	0 (0)	N.A.
	59%	**80%**	**35%**	**55% (16%)**	**43%**

* a suggested fecal coliform standard (≤ 1 per 100 mL)
** a suggested heterotrophic plate count standard (≤ 500 per mL)
N.A. Not Applicable (ultra violet disinfection)

The opportunistic pathogen Ps. aeruginosa was found in 13 of the 17 or 76% of the cisterns at one time or another. It also occurred in the absence of total coliforms. In large hotels Ps. aeruginosa was found in only 13% of the samples, while in moderate and small hotels, it was found in 43% and 55% of the samples respectively. The occurrence of Ps. aeruginosa in the absence of total coliforms ranges from 9% in large hotel cisterns to 18% in the cisterns of moderate hotels. As a whole, of those hotel and guest house cisterns which tested positive for Ps. aeruginosa, 18% were positive for the organism in the absence of total coliform. This figure matches with the data from our previous studies (29,31) of private homes and public housing projects.

Table 4 also reveals the relative percentage of times free residual chlorine was found in each cistern. The average values and ranges are included as Appendix C. The large hotels were the most consistent in their chlorination practices, meeting the EPA guideline of at least 0.2 mg/L from 88% to 100% of the time, while the moderately sized hotels and the small hotels and guest houses had considerable variability.

Chlorination is still the most effective way of reducing microbial growth. When there was treatment, there was an almost four fold increase in the number of samples which were contaminant free compared to samples which received no treatment. When contaminants did survive the treatment process, they tended to cluster in the low range whereas without treatment, they tended to cluster in the high range.

Table 5 presents the occurrence of each contaminant in relation to the free residual chlorine present. It should be noted that the fecal streptococcus organism tended to be the most resistant organism to chlorination and could be found in cisterns with a residual of > 3.6 mg/L. Fecal streptococci can cause skin infections and respiratory diseases such as pneumonia, sinusitus etc.

Ps. aeruginosa too could be found frequently up to 1.0 mg/L, and occasionally up to 3.0 mg/L. This overall resistance may account for the presence of Ps. aeruginosa in the absence of total coliforms (23). Ps. aeruginosa can cause ear infections, urinary tract infection and diarrhea. Looking again at Table 5 we see that 69% of the occurrences of Ps. aeruginosa occurred in the absence of a chlorine residual. Only a small fraction occurred in the presence of a chlorine residual greater than 1.0 mg/L, yet it may well be that this same small fraction is also the one that is present when total coliforms are absent. Essentially their greater resistance to stress in the environment allow them to survive after the coliforms have died off, either naturally, or from disinfection practices (23).

Table 5: Occurrence of Contaminants in Relation to Free Residual Chlorine

Free Cl a	0.0	0.2 - 1.0	1.2 - 2.0	2.2 - 3.0	3.2 - 3.6
No Contam. b	8	20	5	2	1
Total Coliform b	28	12	4	1	1
Fecal Coliform b	17	2	2	0	1
Fecal Strep. b	21	17	8	3	3
Ps. aeruginosa b	29	9	1	3	0

a Free chlorine residual in mg/L (ppm)

b Number of samples positive for the indicated organisms in the given chlorine residual ranges

Again, as in past studies (29,30,31), we have looked at the ratio of fecal coliform and fecal streptococcus. This ratio is based on the fact that man tends to excrete fecal coliforms in greater numbers than fecal streptococcus, while animals tend to excrete greater numbers of fecal streptococcus than fecal coliforms (1). Fecal coliforms indicate the possible presence of enteric pathogens such as Salmonella, Shigella etc.; Salmonella can cause diseases such as typhoid.

Based upon the ratio of fecal coliforms to fecal streptococci, one is able to, in theory, not only identify the area from which the pollution is occurring, but the source of the pollution as well. In general, however, ratios in excess of 4.1 are taken to indicate a predominantly human origin of the coliform bacteria. Ratios less than 0.7 are taken to indicate pollution from non-human sources. Ratios between 0.7 and 4.1 usually indicate wastes of mixed human and animal sources (1,2). Normally fecal coliform/fecal streptococcus ratios are applied to water quality studies of lakes, streams, and estuaries; our purpose for doing these ratios however is one of a qualitative and not quantitative nature. The use of these ratios is not intended to pinpoint an exact source or point of contamination, but rather to aid in determining whether any observable contamination is essentially due to environmental contamination, or whether there might be septic tank infusion.

From Table 6 it becomes clear that since both the fecal coliform/fecal streptococcus ratios are low, and the fecal streptococcus counts are less than 100, the source/s of the contamination is of environmental, rather than anthropogenic origin, and is consistent with our previous findings (29,31).

Table 6: Ratios of Fecal Coliform to Fecal Streptococcus

Cistern No.	Sample Date	Total[a] Coliform	Fecal[a] Coliform	Fecal[a] Strep.	FC/FS Ratio	Cistern No.	Sample Date	Total[a] Coliform	Fecal[a] Coliform	Fecal[a] Strep.	FC/FS Ratio
L 1-1	02/06/89	4	2	43	0.05	M 2-1	10/28/88	120	0	2	0.00
L 1-1	03/06/89	0	0	5	0.00	M 2-1	02/06/89	2	0	35	0.00
L 1-1	04/10/89	16	0	8	0.00	M 2-1	03/06/89	1	1	26	0.04
L 2-1	01/24/89	0	0	16	0.00	M 2-1	04/10/89	6360	0	11	0.00
L 2-1	02/14/89	1	0	1140	0.00	M 2-1	06/05/89	>200	284	0	N.D.[b]
L 2-1	04/11/89	0	0	6	0.00	M 3-1	01/17/89	127	229	56	4.09
L 2-2	01/24/89	0	0	18	0.00	M 3-1	02/13/89	0	0	44	0.00
L 2-2	02/14/89	0	0	11	0.00	M 3-1	03/27/89	2	0	627	0.00
L 2-2	04/11/89	0	0	57	0.00	S 1-1	10/29/88	214	6	60	0.10
L 2-3	01/24/89	0	0	21	0.00	S 1-1	11/09/88	380	4	36	0.11
L 2-3	02/14/89	0	0	28	0.00	S 1-1	02/07/89	25	2	307	0.01
L 2-3	04/11/89	0	0	4	0.00	S 1-1	03/13/89	76	2	55	0.04
L 3-1	01/17/89	6	4	9	0.44	S 1-1	04/10/89	13	0	12	0.00
L 3-1	02/07/89	0	0	128	0.00	S 1-1	05/30/89	6	32	14	2.29
L 3-1	03/21/89	0	0	9	0.00	S 1-1	06/26/89	13	5	0	N.D.[b]
L 4-1	01/31/89	3	3	59	0.05	S 2-1	01/30/89	5	3	58	0.05
M 1-1	01/31/89	4	0	6	0.00	S 2-1	02/13/89	1	0	49	0.00
M 1-1	03/14/89	2	14	2	7.00	S 2-2	01/30/89	9	0	145	0.00
M 1-1	04/13/89	17	1	21	0.05	S 2-2	02/13/89	0	0	62	0.00
M 1-2	01/31/89	0	0	13	0.00	S 2-2	07/11/89	0	0	3	0.00
M 1-2	03/14/89	58	55	94	0.59	S 3-1	02/07/89	4	0	60	0.00
M 1-2	06/05/89	153	30	0	N.D.[b]	S 3-1	04/13/89	17	0	14	0.00
M 1-3	01/16/89	114	2	1	2.00	S 4-1	01/23/89	2	35	1	35.00
M 1-3	01/31/89	0	0	9	0.00	S 4-1	02/27/89	1	0	10	0.00
M 1-3	03/14/89	95	40	66	0.61	S 4-1	03/27/89	0	0	3	0.00
M 1-3	04/03/89	98	11	341	0.03	S 4-1	06/19/89	804	1	50	0.02
M 1-3	06/05/89	239	58	7	8.29	S 4-2	03/27/89	0	0	5	0.00

a Counts are given per 100 mL. Only samples containing more than one Fecal Coliform or more than one Fecal Streptococcus are reported.

b Not Determined

DISCUSSION

The water quality of hotels and guest houses varied greatly. The large hotels that were sampled were in compliance with the SDWS more after than the small and moderate sized hotels and guest houses. Of the nine hotels which filled their cisterns either from the potable water lines and/or purchased (trucked) water, seven relied at least to some extent on passive chlorination -- that water sold either directly or indirectly by the Virgin Islands Water and Power Authority (WAPA) containing free residual chlorine as a result of their chlorination practices, and not due to any effort on the part of the purchaser. Indeed for at least two of those hotels and guest houses (S-2, M-3) that was indeed the only chlorination that the water received. Thus the cistern water quality of those hotels which rely entirely or in part on WAPA's chlorination practices will be to some degree suspect for two reasons: Should WAPA for any reason fail to chlorinate their water supply, the water entering the cistern could very well be contaminated (8,20,27,31). If the water has a slow turnover rate of consumption, any initial free residual chlorine will either be used up and/or liberated to the air, which is usually within 3-5 days (29); thereafter the water is susceptible to either regrowth due to bacterial contaminants from within the system -- which could come from either the bottom sediment sludge usually found in cisterns or from any suspended turbidity particles in the water column -- or from new input due to a rainfall (29).

Chlorination is still the cheapest and most reliable source for disinfection (10,20,24,26); yet chlorination for all its effectiveness does not guarantee that the water will be safe to drink (20). Factors such as turbidity, pH, and bacterial adaptations play a role in overall chlorination efficiency. Bacteria such as Bacillus, an aerobe, and Clostridium, an anaerobe can form spores which can withstand chlorination (9); some bacteria are naturally resistant, while others contain plasmids which can convey resistance; other organisms such as viruses and protozoa show various patterns of resistance to chlorination. Turbidity too plays a role (12,32). Turbidity in the water allows bacteria to clump onto a particle, with some bacteria atop other bacteria. During chlorination the outer most bacterial layer will be killed, while others towards the center of the particle may survive to go on to recontaminate the water, even though it has been treated. The particle can also react with the free chlorine thereby reducing its concentration. What chlorination does do is provide a high degree of probability that the water will be safe to drink, since the vast majority of microorganisms are susceptible to its effects.

Enforcement of the provisions of the SDWA, while not a guarantee about the overall safety of drinking water supplies, goes a long way towards that goal. Lax enforcement of those laws for whatever reasons allows room for noncompliance situations to develop. New EPA regulations governing water quality will come into effect in 1991 and many public health microbiologists feel these amendments are long overdue; however, these additional regulations will mean additional expense. While most hotels will be able to meet the new fecal coliform standard, few will be able to consistently meet the new heterotrophic count standard if our results are any indication. The additional expenses coupled with be a greater number of samples which are likely to be in non-compliance can only serve to increase the likelihood that there will be more hotel and guest house owners/operators who may try to forgo having their water tested. The best way then to address the potential problem is to encourage voluntary compliance by establishing meaningful cistern water quality standards such as testing for fecal coliform, Ps. aeruginosa and standard plate count.

SUMMARY

About one-half of the cisterns exhibited a significant presence of total coliforms. Approximately one-third of the cisterns showed the presence of fecal coliforms. We believe that the fecal coliform count is a better indicator of true risk than the currently used total coliform count because of the largely non-anthropogenic (non human origin) coliform contributions found in cistern water supplies. The total coliform may therefore not be the most appropriate indicator for cisterns.

Ps. aeruginosa was found in 76% of the cisterns; 18% of those samples contained Ps. aeruginosa in the absence of total coliform. These data agree remarkably well with our prior studies done on the cistern water quality in private homes (29) and in public housing projects (31).

Most of the hotels and guest houses in this study had pH values and turbidity readings well within acceptable ranges. Probably the biggest problem for cistern water users, especially those who supply water to the public, is turbidity due to resuspension. In places which use a lot of water, the turnover time for the water in the cistern is short; as the water level falls, any disturbance of the sediment layer, will tend to resuspend debris in the water column, leading to non-compliance for turbidity.

RECOMMENDATIONS

The following recommendations are made based upon both laboratory results, and from information obtained from EPA and hotel owners/operators:

1. Realistic water quality regulations should be established to cover cistern water systems. These regulations should be specific and reasonable in scope, yet should provide adequate protection to public health.

2. The Virgin Islands Water and Power Authority should expand their water testing procedures, so that samples are not only collected from the main potable water line, but from each of its major branch lines as well. These samples should be tested for both total coliform and heterotrophic bacteria.

3. Hotel and guest house owners/operators should be required to test water on a quarterly basis for fecal coliform and Pseudomonas aeruginosa.

4. Hotel and guest house owners/operators should test water on a daily basis for turbidity and chlorine residual, and additional chlorine should be added if it is less than 0.2 mg/L.

5. If chlorination is not used for disinfection purposes, the hotel or guest house owner/operator should submit a manufacturer's statement of the effectiveness of the treatment process used as well as a daily log of use and maintenance. In addition, testing for fecal coliform and Pseudomonas aeruginosa should be done on a monthly basis.

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